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Investigation of the LIZ-3 Dew Line Station Water Supply Lake

Austin Kovacs

April 1990

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U.S. Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

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PREFACE

This report was prepared by Austin Kovacs, Research Civil Engineer, Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. This study was funded by the Department of the Air Force, 4700th Air Defense Squadron (Support) (TAC), Peterson Air Force Base, Colorado.

The support provided by the LIZ-3 Dew Line Station personnel during the field survey is appreciated, as is the background information and advice given by Frederick Crory of CRREL, who also arranged for the field work. The field assistance of Rexford M. Morey, Consultant, the helpful advice of Sherwood Reed and Thomas Jenkins of CRREL on aspects of water quality, and the review of this report by Sherwood Reed and Dr. Ronald Liston, are also acknowledged.

Investigation of the LIZ-3 Dew Line Station Water Supply Lake

AUSTIN KOVACS

INTRODUCTION

LIZ-3 Dew Line Station is located on the Alaskan North Slope about five miles southwest of the village of Wainwright on the Chukchi Sea coast (Fig. 1). The primary water supply for the station is from lake A located about one mile to the north. This lake is easily accessible by way of a gravel road (Fig. 2). Water is drawn from this lake for six to seven months, beginning about June, when the lake ice begins to melt, and extending to about the first of the new year, when the lake is nearly totally frozen. Water is no longer drawn from the lake when 15 cm or less of water remains under the ice at the withdrawal site. At this point, according to James Manning, Station Chief, the water becomes too "sour" for domestic use. From this time until spring melt, the station must rely on the water available in four heated 20,000-gal. (~ 75,000-L) storage tanks. This supply was not adequate in 1984, and the station bought water from the village of Wainwright, which was also having water shortage problems. In short, water availability from the village cannot be relied on.

Water is currently taken from lake A at a site where the depth was about 1.25 m but is now 0.9–1 m deep due to a recent lowering of the lake level.* This lowering apparently started two to three years before the 1984 survey. Leakage is to a low natural drainage area on the southwest side of the lake. This depressed area, outlined by the dashed line shown to the west of lake A in Figure 3, appears to have been part of the existing lake prior to a lowering event many years ago. The concern at LIZ-3 is not only that the lowering has reduced the water depth and therefore the length of time during which water may be drawn from the lake, but also that the lake may experience a further, and possibly rapid, drainage. This concern is based in part on the fact that several lakes in the area of LIZ-3 have drained in recent years (Fig. 3).

Drainage from water supply lake A is occurring through a thermal crack that intersects the southwest shore line (Fig. 4). LIZ-3 station personnel indicate that the crack is becoming deeper each year and in places may be 1.8–2.4 m deep. Efforts have been made to fill the crack in the hope of stopping further lake drainage. This effort has included filling the crack with sandy gravel, plastic and wood materials. While this has helped to reduce the outflow, seepage is still occurring.

Should lake A drain suddenly, the nearest lakes with enough depth to provide water until about January of each year, when in-house storage would again have to be relied on, are lakes B and C (Fig. 3). These lakes are located about 3 and 5 miles, respectively, from the station. The lakes were apparently used for water in past years, when the station population was larger. However, the station may not currently have the equipment and

* Personal communication with J. Manning.

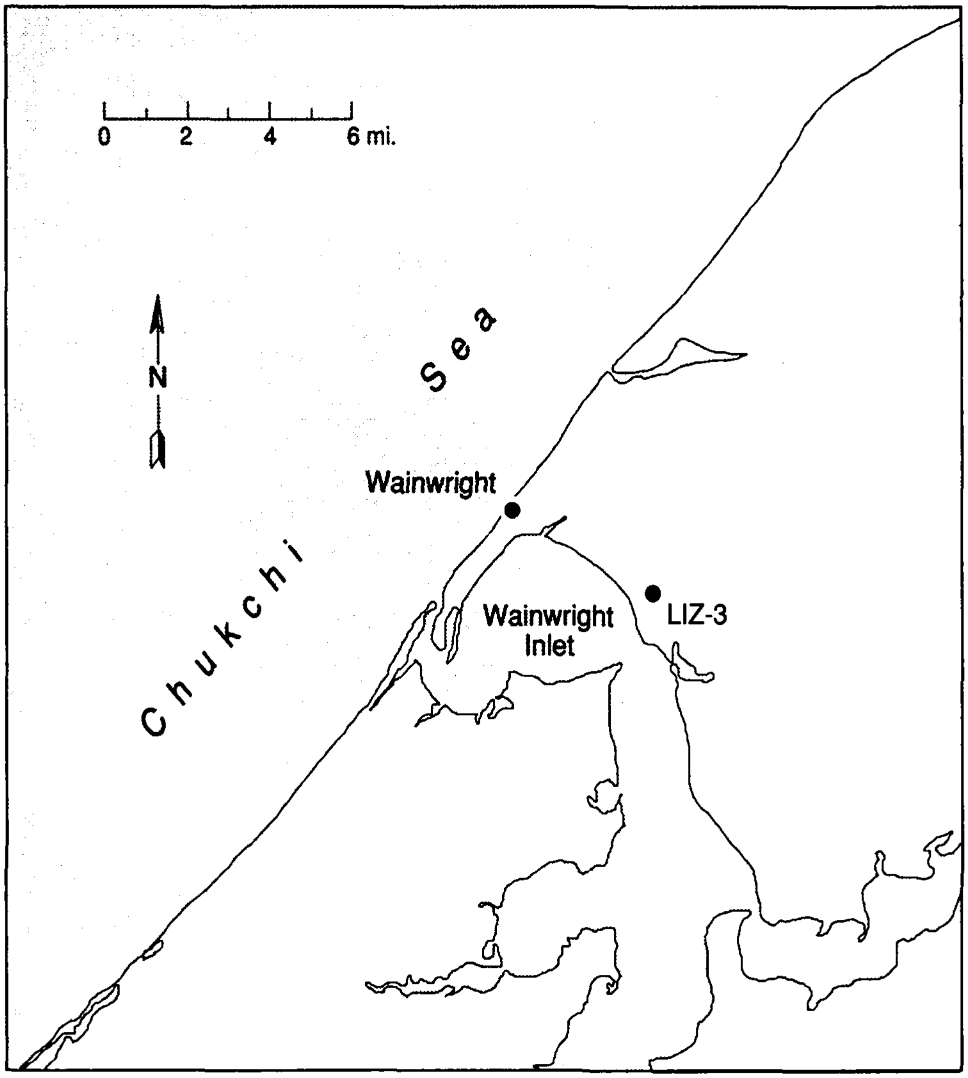


Figure 1. LIZ-3 Dew Line Station location.

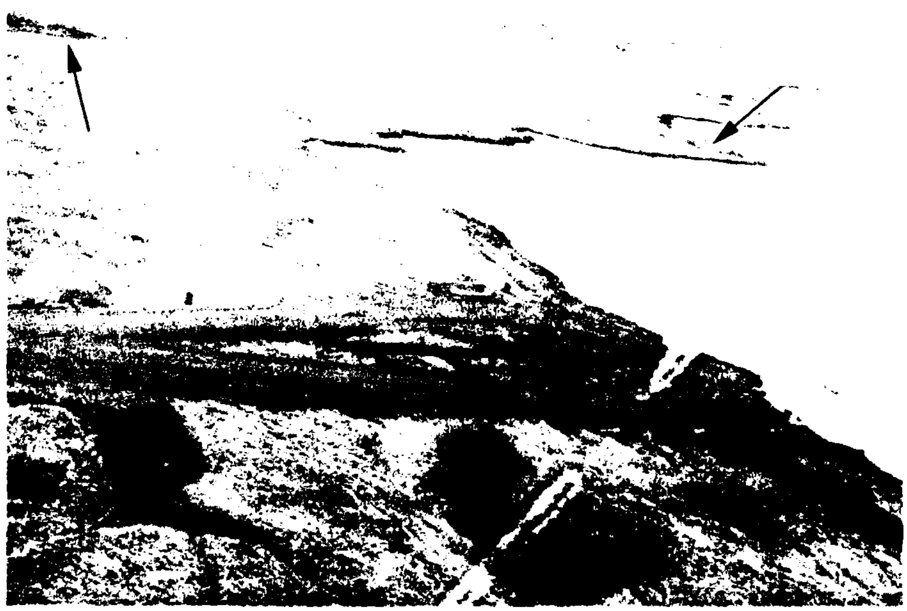


Figure 2. Gravel access road to water supply lake A. The left arrow points to an ice mound, and the right arrow points to the "dam site." (Photograph by F. Crory.)

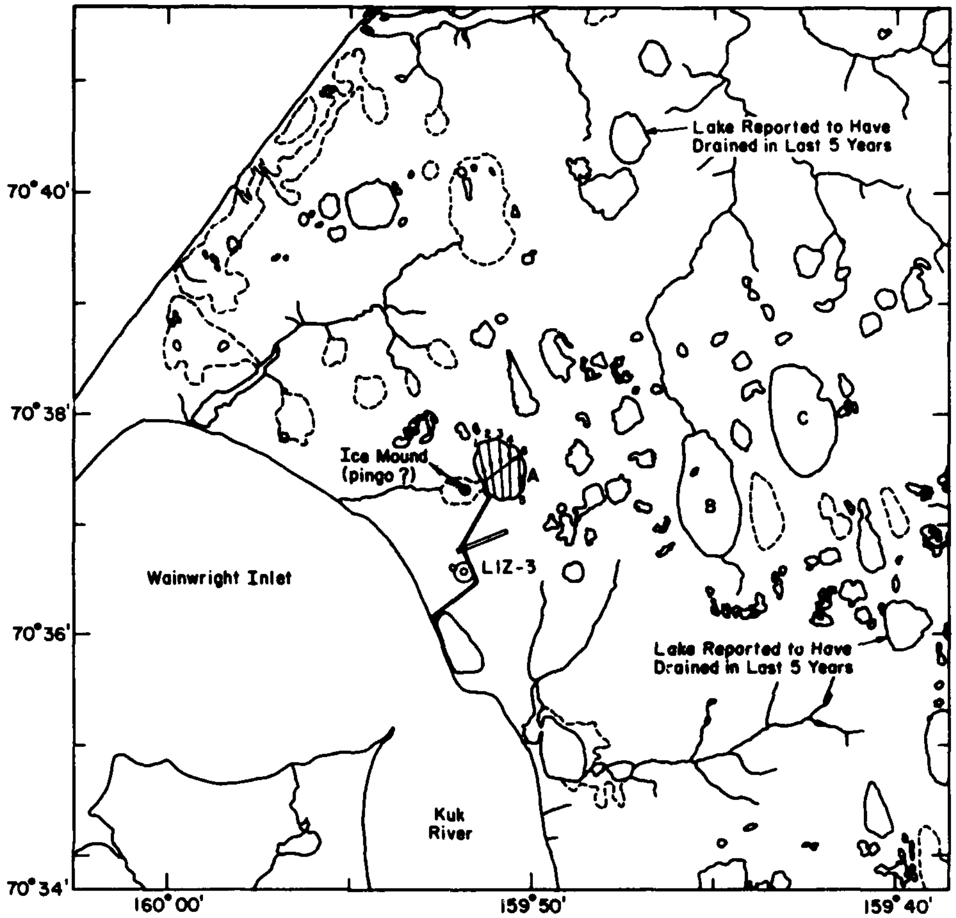


Figure 3. Lakes A, B and C location map. The information on recently drained lakes was obtained from J. Manning.

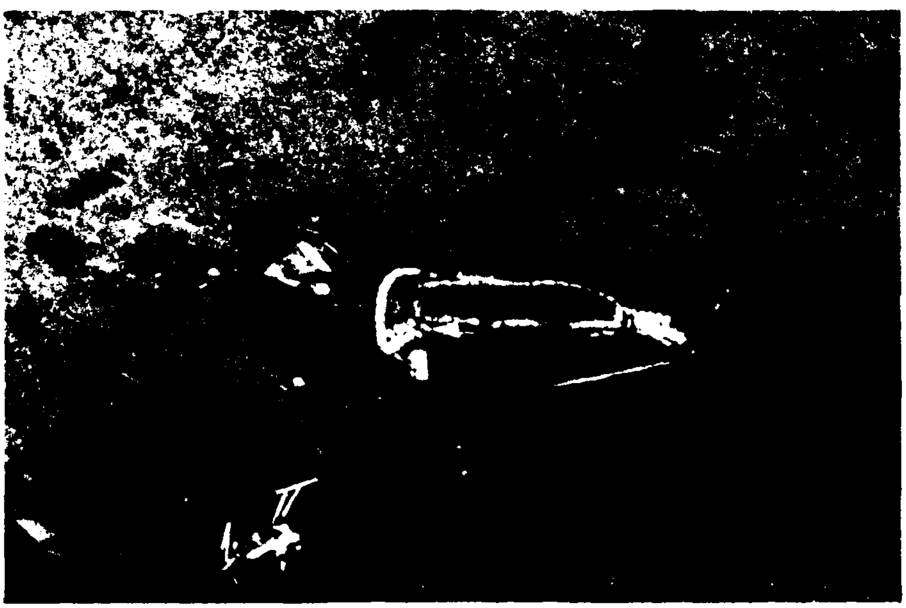


Figure 4. Thermal crack drainage channel on the west side of lake A and the makeshift dam built to reduce outflow. (Photograph by F. Crory.)

manpower necessary to haul water overland in winter. Wainwright Inlet contains brackish water, which is thus not usable for human consumption. Clearly, continued availability of water from easily accessible lake A is desirable.

A recent report by R&M Consultants (1984) mentions that a 44- × 45- × 4.6-m-deep pit excavated into the lake bottom is being considered by the Air Force to provide a year-round water supply. With this arrangement the need for maintaining the four 20,000-gallon storage tanks could be eliminated, along with the significant cost of the fuel now required to heat the tanks to prevent freeze-up. A reservoir pit this size would retain over one million gallons (~3.8 million liters) of water by the end of the winter. A reservoir of this size is far in excess of the station's requirements.

After reviewing the R&M Consultants report, the Air Force decided that before any decision on improving the LIZ-3 water supply was made, the depth throughout lake A should be measured to determine if the lake has a deep area from which water may be withdrawn later into the winter than is currently done. If such a depression exists, then further attention should be directed toward stopping the present leakage and arranging to take water from the deeper water area, assuring continued use of the lake for the station's water supply needs.

FIELD SURVEY

In early May 1984 we received a request to profile the depth of lake A. This was done on 19 May using an impulse radar sounding system, which had previously been shown to be useful for profiling freshwater ice thickness, detecting water under frozen lakes and profiling the depth of water under lake ice, both on the surface and from a helicopter (Kovacs and Morey 1978, 1979, 1985). The system works similarly to an acoustic-profiling system used for profiling marine sediments. This sounding system provided a profile of the ice/lakebed interface with the use of a transmit–receiving antenna towed along the snow surface (Fig. 5). The echoes returning from the ice/lakebed interface, which were displayed in real time on a graphic recorder, provided a continuous trace of ice thickness along the survey routes.

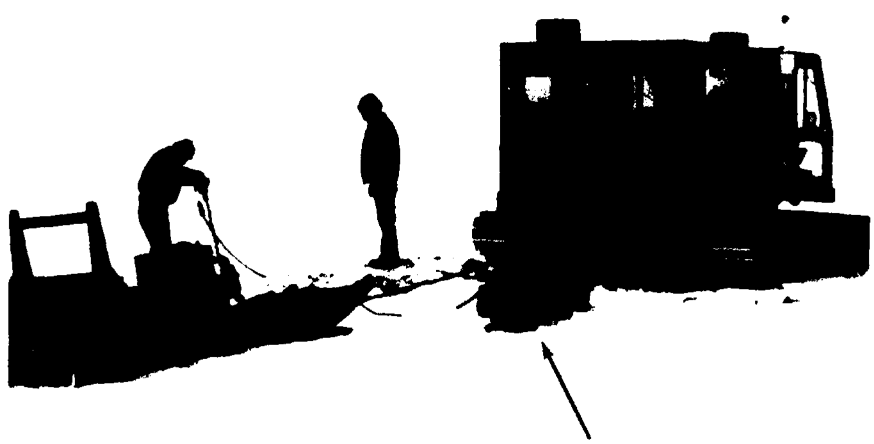


Figure 5. Equipment used in survey. The arrow points to the two antennas used. The larger one operates at about 300 MHz, and the smaller, darker antenna at about 550 MHz. The generator is pulled on the sled. The driller is cutting a slanted hole into the pingo-like ice mound.

Six transects were made across the lake. Five were run in a north–south direction and one was made in an east–west direction, as shown by the lines in Figure 3. Other short runs were made along the west shore and on the shore ice in the area of the thermal ground crack, or what is called the dam site by station personnel. The sounding records obtained along transect runs 3, 4, 5 and 6 are shown in Figure 6. The records indicate an undulating lakebed surface. The variation is typically about 15 cm. However, this relief is not lakebed microtopography but was caused by depth variations in snowdrifts over which the sounding antenna was towed. The deepest part of the lake was practically flat and did not have more than 1.4 m of ice (water in summer). The records show that the lake is shallowest along the north and east shores but increases rapidly in depth along the southwest shore; this is particularly evident in Figure 6d. From this record we find that the lakebed reached its deepest area about 250 m from the east shore, but at the dam site on the west shore, deep water existed less than 30 m from the shore. The ice depth scale for the records was determined by direct drill hole measurements. One drill site is shown in Figure 6d.

On runs 2, 3 and 6 a subbottom interface appeared *in the graphic record (Fig. 6a and d)*. This feature covered an area about 275 m in diameter. The electromagnetic (EM) wavelet flight time from the ice bottom to the internal layer back to the ice bottom was about 9 ns. If we assume that the intervening material was frozen silt with an apparent bulk dielectric constant E_r of 6, than we can estimate the depth D below the lakebed from

$$V_e = \frac{C}{\sqrt{E_r}} \qquad (1)$$

where V_e is the effective velocity of EM wavelet and C is the freespace EM velocity $(3 \times 10^8 \text{ m/s})$, and then

$$D = V_e \frac{t}{2} \qquad (2)$$

where t is the two-way EM wavelet travel time in the material. From these equations we estimate that the internal layer is about 0.55 m below the lakebed. The interface may be the demarkation between frozen and unfrozen soil.

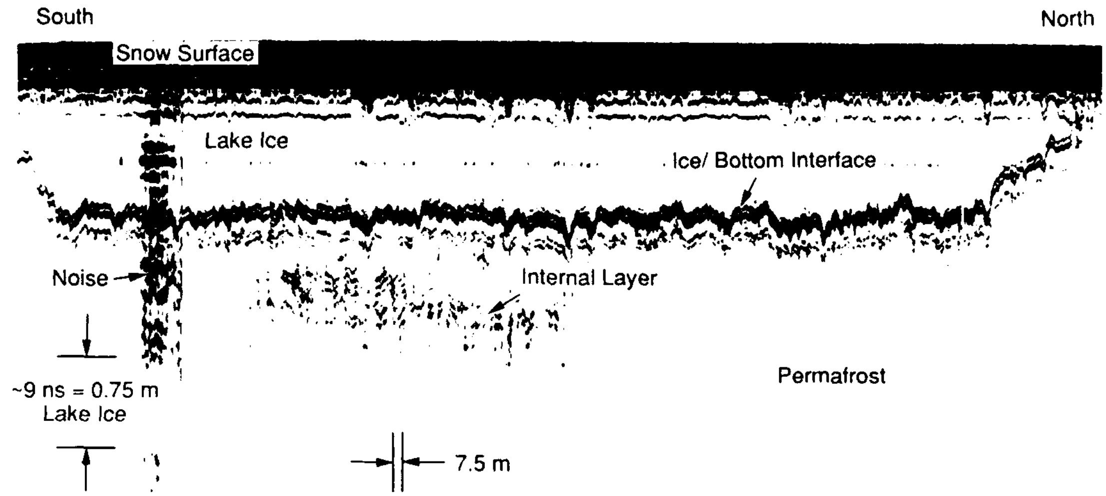
It is possible that a thaw bulb exists in the surrounding permafrost below this interface. Thaw bulbs are common below deep lakes on the North Slope. Simple hand-operated drilling equipment can be used to verify this. We suggest that this be done prior to selecting a site and an excavation method for deepening lake A. If a reservoir pit appears desirable, this area may be the easiest to excavate.

In any event, our survey results showed that the lake does not have a deep area from which water can be withdrawn very much later into the winter than is presently done. Nevertheless, even a one-month extension would be very significant. The records also suggest that if the thermal crack in the ground should deepen and uncontrolled leakage occur, the lake could drain since the lake bottom drops quickly to its deepest level near the area of the thermal crack drainage channel. Water flowing out of the lake at this location could erode a trench in the lakebed connecting the thermal drainage channel to the deeper portion of the lak Should this occur, the lake could drain completely. How long this would take is unknown.

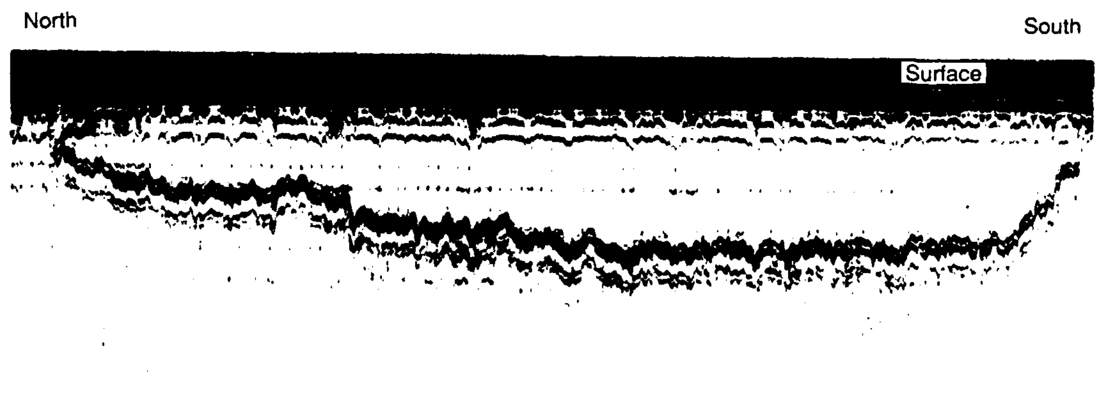
About 200 m west of the dam site the drainage channel passes through a newly formed ice mound. This feature is about 1 m high and has the appearance of a small pingo. Station personnel stated that the feature began to form about 1982 after significant outflow from the lake had occurred. The mound is reported to be increasing in height each year. An impulse radar sounding survey was *made over this mound*. The graphic record revealed a subsurface feature, which we assumed to be ice (Fig. 7). A 5-cm-diameter hole was drilled into the mound at the location shown in Figure 7. The first 20 cm was found to consist of organic soil and silt. Below this layer we penetrated 1.3 m of ice, followed by coarse-grained material that our drill did not penetrate. After drilling the exploration hole, we discovered, under the 0.3-m snow cover, a crack transecting the mound (Fig. 8). The crack was about 5 cm wide at the surface but rapidly narrowed with depth. At 0.6 m below the surface the crack narrowed to the 1-cm-diameter of our probe. This ice formation may continue to grow as long as water reaches the site via the drainage channel.

DISCUSSION AND RECOMMENDATIONS

It appears appropriate to prevent further drainage through the area of the thermal crack. We recommend that a 10- to 20-cm-wide slot be cut parallel to the shoreline about 15 m inland. The slot should be cut to a depth below the base of the thermal crack. This depth would be a minimum of 1.8 m, but 2.5 m might be required. An impermeable flexible rubber liner would then be placed in this



a. Survey line 3.



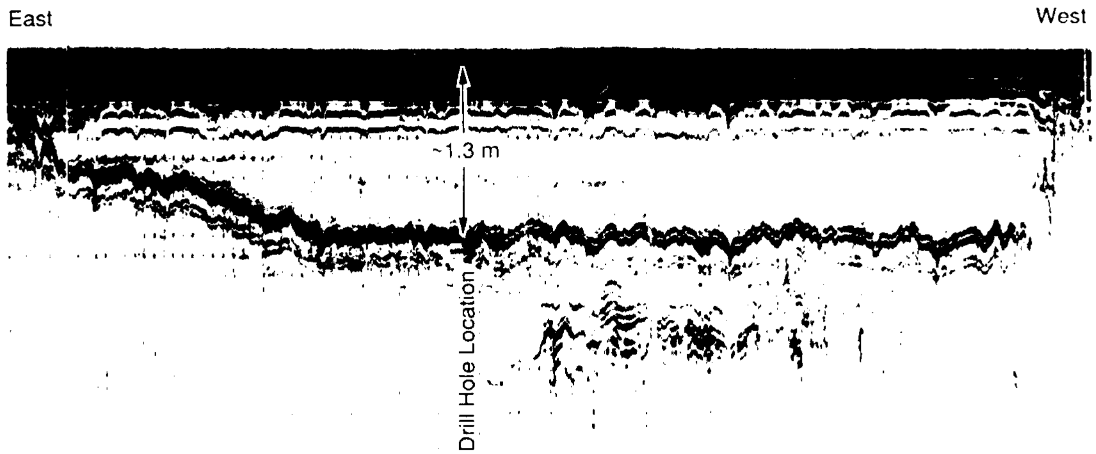
b. Survey line 4.

Figure 6. Graphic record of impulse radar sounding data obtained along four survey lines.

trench to prevent further water movement downslope. The trench would then be backfilled with the cuttings removed during excavation or with some other suitable material such as silt from the lakebed or a sand–cement grout. Freezeback of the fill will occur in a short time, and the fill below the depth of summer thaw (<0.7 m) will remain frozen year-round. During construction of the cut-off trench, extreme care must be taken to prevent undue disturbance of the protective vegetative ground cover. This natural cover acts as a thermal blanket, protecting the underlying frozen ground from melting under the effects of summer solar radiation. Should this cover be damaged, progressive melting of the underlying frozen ground could occur and new leakage outlets might be formed. For this reason it is recommended that the cut-off trench location be determined during the summer and construction be done in the spring, when the ground is frozen and resistant to damage by heavy equipment.

The length of the cut-off trench would have to

c. Survey line 5.



d. Survey line 6.

be determined by field inspection. A length of about 60 m would seem more than sufficient. Machines (DitchWitch, etc.) capable of excavating the cut-off trench are available on the North Slope in both Barrow and Prudhoe Bay. The trench can probably be cut in one to two days. If a cut-off wall is installed, one can expect that the lake will at least stabilize at its present level; it might rise to its former elevation.

Deeper water can be found about 30 m farther offshore than at the site where water is currently withdrawn. Therefore, one could expect that water from the lake could be obtained longer into the winter than is now possible if the withdrawal site were moved. However, since the water becomes more and more sour as ice growth continues, the water in the deeper part of the lake may not be suitable for domestic use. This aspect of water quality needs to be assessed. It is well known that organic and dissolved minerals are concentrated in water under an ice cover as a result of the impurity rejection process that occurs during ice growth. The problem for the LIZ-3 water source is: Is the contamination a health problem? A review

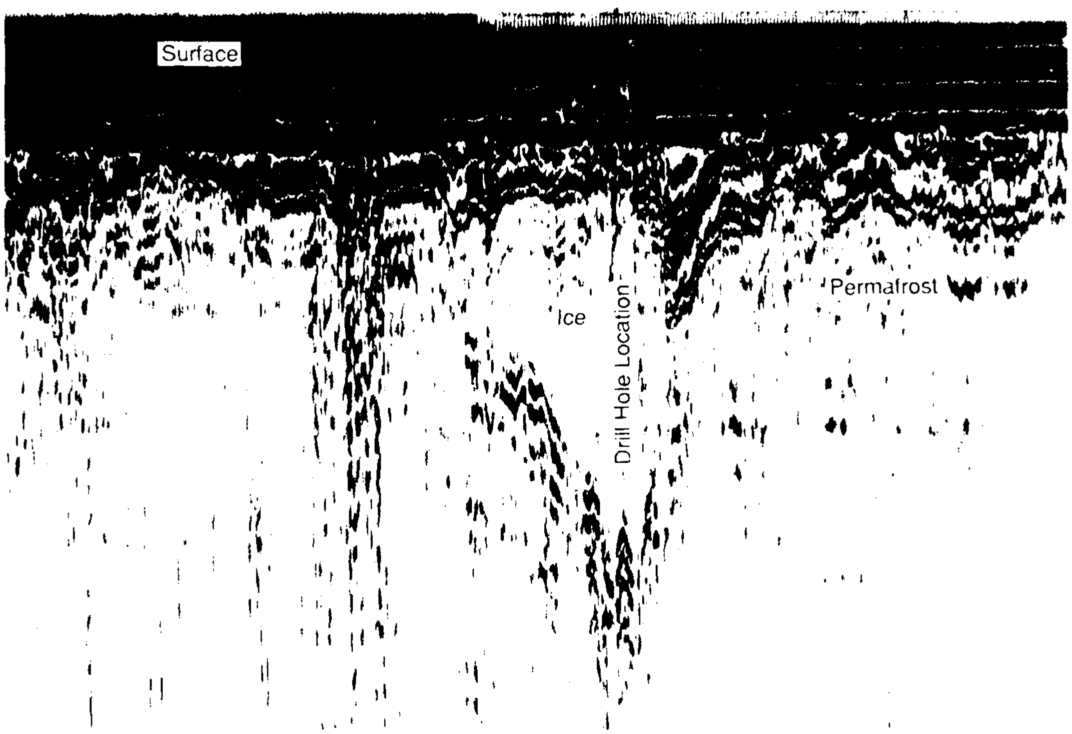


Figure 7. Graphic record of impulse radar data taken on a transect over the ice mound. The massive ice is 2.5–3 m wide.

Figure 8. Crack passing through the top of the ice mound. The drill hole is shown by the arrow.

of the weekly or monthly water quality reports should quickly answer this.

Reed et al. (1984) point out that ponds on the North Slope can be contaminated by animals, birds or human activity in the watershed. They added that:

> "The water quality in shallow lakes and ponds tends to deteriorate in the winter due to the concentrating effect of the ice. If ice is formed at relatively slow rates it will be composed of essentially pure water molecules and most of the suspended and dissolved matter originally in the water will be rejected and will accumulate in the remaining unfrozen liquid. In the practical case there will always be air bubbles and microscopic inclusions of unfrozen water remaining in the ice, so rejection is not 100% efficient. Research in western Canada with natural freezing of brackish ponds indicated that the ice contained about 20% of the salts that were in the original unfrozen water (Fertuck 1969).
>
> If the 20% is adopted as a rule-of-thumb and an assumption is made regarding the density of the ice (say 0.8 g/cm³), it is possible to estimate the concentration of a substance in the remaining liquid for a particular thickness of ice, depth of pond, and the original concentration of the same substance in the original unfrozen water. It is possible to avoid repetitive calculations by normalizing both sides of the equation:
>
> $$\frac{\text{concentration in liquid under the ice}}{\text{original unfrozen concentration}} = f\left(\frac{\text{ice thickness}}{\text{original pond depth}}\right)$$
>
> or:
>
> $$C = f(I)$$
>
> where C = concentration increase (%)
> I = ratio of ice thickness to pond depth.
>
> The boundary conditions for this equation are:
>
> when $I = 0$, then $C = 1$, since there is no ice and no concentration effect
>
> when $I = 1$, then $C = \infty$, as the concentration increases in the last drop of water just before it freezes.
>
> With relatively pure water, I can in fact be equal to 1 and the pond would freeze solid. In the practical case it is unlikely that the pond would be a usable water source if I exceeded 0.8. Adopting that as the upper limit, the following expression can be developed to estimate the concentration increase:
>
> $$C = 1 + 1.72\, I^{(1.56)}$$
>
> where C = concentration increase = C_f/C_o
>
> $$I = \frac{\text{ice thickness}}{\text{pond depth}}$$
>
> C_f = final concentration
> C_o = initial concentration
>
> Figure [9] can be used for graphic solutions of this equation."

The above gives insight into when the pond water may no longer be usable for domestic purposes. Verification of this for lake A should be determined from water quality test data.

We assume that diffusion of the minerals, rejected as the ice grows, will occur relatively uniformly throughout the remaining water body. In this case it would make no difference whether or not the water was taken at the current shallower

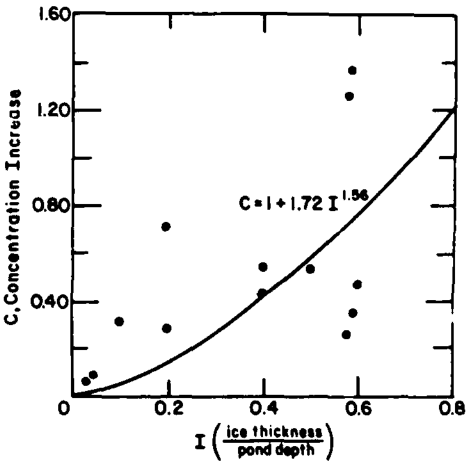


Figure 9. Concentration increase of substances in liquid remaining under an ice cover in shallow ponds. (From Reed et al. 1984.)

near-shore site or out in the deeper water. The quality of the water should be comparable.

It is probable that the reference to sour water as expressed by the user is a matter of taste and not based upon health considerations. The sour condition may be the result of impurity concentration under anaerobic conditions, which undoubtedly exist in the very quiescent water column under the lake ice. This condition could be avoided with the use of a simple air bubbler system installed in a small storage tank. The resulting precipitate would then be removed by a simple filter. Thus it may be possible to use more of the lake water later into the winter. While this would have to be studied, positive findings would be far-reaching in terms of improving the water quality and supply availability time for LIZ-3 and perhaps other North Slope facilities.

A proposal to excavate a 45- × 45- × 4.6-m pit in the bed of lake A has been suggested to provide a year-round water supply. One method suggested for excavating the pit is to use explosives to break up the frozen soil and dozers to push this material aside (R&M Consultants 1984). This procedure can be done with on-site dozers and a small drill rig (a system weighing 1–2 tons) brought in for the task. We do not support their suggestion to use shaped charges to make holes for the explosive material. Shaped charges are inefficient and will not provide the uniform hole diameter desired for placing explosives for cratering in frozen ground. A review of required explosives, drilling system etc. is in order but beyond the scope of this report. A comparison also needs to be made with other methods for excavating the pit. This includes the use of a ripper on a D-8 type tractor. This method of excavating a pit should be quite effective in the frozen fine-grained material and ice found under lake A (see R&M Consultants 1984 for borehole soil findings). Another method that would be very effective in excavating this material is a 245 Caterpillar backhoe. This machine weighs 135,000 lb and has the demonstrated capability of ripping apart frozen fine-grained material. The smaller 235 Caterpillar backhoe (86,000 lb) may also be capable of doing the task. Further checking would be required to determine this. In any case, both units have booms long enough to excavate well beyond the 4.6-m depth specified. In all cases, excavation would proceed after the lake ice was frozen to the bottom.

Each excavation method should be evaluated in terms of cost and expected water quality. In considering the former, one should determine how existing on-site construction equipment may be used and how equipment may be brought in from Barrow by land, barge, etc. If blasting is the preferred method from the cost point of view, will the water quality be affected by the explosive residue? Probably not.

Finally, it may be more cost effective to excavate a reservoir beside lake A with an interconnecting channel. The quality of the lake water will not be affected by this, and the excavation could proceed during the warmer months.

The size of the reservoir pit required and the need for the pit should be reexamined in light of the station's water needs, the fact that undesirable leakage through the thermal crack in the ground can be arrested relatively inexpensively with the use of a cut-off wall as previously discussed, and the possibility that the sour taste of the water may be alleviated with a simple aerated storage tank.

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The level of a lake supplying water to the LIZ-3 Dew Line Station, near the Chukchi Sea coast of Alaska, had fallen about a quarter of a meter. This lowering reduced the availability of water to the station during the winter and raised concern that the lake may continue to drain. A radar subsurface sounding survey of the lake was made in May 1984 to determine if the lake contained a deep area from which potable water could be drawn from under the ice during the winter. No acceptable deep areas were found. Recommendations are provided for preventing further drainage of the lake and for deepening a portion of the lake. A possible solution for making the sour water remaining under the winter lake ice acceptable for consumption is also presented.

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